Findings on the effects of air pollution on forest and rangeland resources

Ozone effects on resources


Ozone injury symptoms on red alder from USFS PNW publication GTR 495

The Forest Pest Management (FPM) index and the Ozone Injury Index (OII) are the two most widely used indices of O_3 injury to pines. The FPM index has been used to survey tree injury in the Sierra Nevada, mainly in the Sequoia and Sierra national forests where ongoing studies of plots have continued since 1977. The OII has primarily been used to measure tree injury in the mountains of southern California, particularly the San Gabriel and San Bernardino mountains (Arbaugh et al., 1998). In addition, several independent studies have been made regarding forest health related to exposure of O_3 pollution (California Environmental Protection Agency, 2002).

Ozone exposures vary depending upon location within the State. The amount of exposure is most evident in southern California where concentration levels are highest and the exposure time is greatest. In the San Bernardino and San Gabriel mountains, selected forests adjacent to the Los Angeles Metropolitan Area experience high O_3 exposures and sites downwind from pollution sources experience moderate to high O_3 exposures (Takemoto et al., 2000).

Ozone exposure within the Sierra bioregion is moderate, mainly in the Southern Sierra Nevada mountains where forests are directly adjacent to the lower San Joaquin Valley. Ozone exposures lessen moving north along the mountains (Cahill et al., 1996).

Plant species have varying degrees of sensitivity to O_3 exposure. Additionally, annual injury amounts vary from year to year. Assessments made at three to five year intervals allow adequate time for quantifying O_3 impacts over time (Takemoto et al., 2000). Ponderosa and Jeffrey Pine are the most sensitive conifer tree species in California to O_3 and are among the most valuable timber resources in the State. Ozone, combined with other stressors such as drought, makes timber resources more vulnerable to disease, fire, and pests. Ozone also causes the break up of biological molecules such as DNA, destroying their function. Ozone can reduce the length of time that a tree retains needles from the average time interval of five to six years down to two years. This greatly affects tree growth.

Ozone has also been found to have a greater affect on needles in high moisture conditions. Thus, trees have sequential impacts on health by both exposures to O_3 impacts during normal moisture years and drought stresses during low moisture years (Miller, 1996).

Detection of O_3 injury in the Sierra Nevada mountains has been highlighted in the SNEP report. Studies of O_3 injury to pines reported in the SNEP report suggest the following (Miller, 1996):

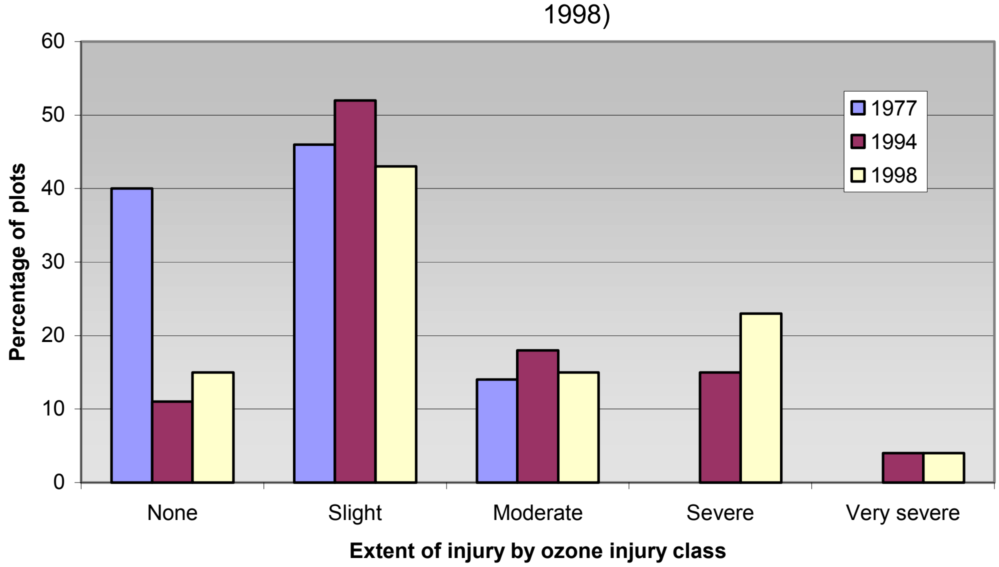
- The southern Sierra Nevada mountain forests are the most susceptible and infected areas to damage.

- In 1986, 39 percent of the trees sampled in Sequoia-Kings Canyon National Park and 29 percent of trees sampled in Yosemite National Park had detectable O_3 damage symptoms.
- No large-scale growth reductions have occurred to date.
- In 1989, the most exposed Jeffery pine studied in the Sequoia-Kings Canyon National Park had reduction in growth up to 11 percent.
- Trees in the northern portion of the O_3 sampling area in Lake Tahoe show 21 to 29 percent with O_3 damage symptoms.

The FPM Program has monitored O_3 injury extensively in the southern Sierra Nevada mountains. In 1997, roughly 35 percent of trees monitored in the Sierra National Forest had O_3 injury symptoms. Within the Sequoia National Forest (located further south), 45 percent of trees monitored had O_3 injury symptoms (Figure 4).

It is important to note that earlier studies for SNEP reported that 39 percent of trees sampled in Sequoia National Park had O_3 damage symptoms. A more recent 1997 study suggests that O_3 injury is increasing within the Sequoia National Forest. Measured amounts of damage within the Sequoia National Forest showed 42 percent of monitored plots with O_3 injury symptoms fell into the moderate, severe, and very severe O_3 injury classes (Figure 4).

Figure 4. Percentage of plots injured due to ozone exposure, Sequoia National Forest (1977, 1994, and 1998)



Source: Campbell et al., 2000

In the San Bernardino mountains, results from the OII showed a west to east gradient of decreasing injury. Average injury amounts were higher than in the Sierra Nevada mountains. Throughout much of the San Bernardino mountains, many of the most O_3 sensitive trees died due to the combined effects of O_3, drought, and insect attack since the 1950s (Miller and Mcbride, 1999), (Takemoto et al., 2000).

Nitrogen effects on resources

When nitrogen is in abundance, trees may consume excessive quantities, which could be detrimental to their long-term health.

Oxides of nitrogen (NO_x) are produced mainly from motor vehicle exhaust, prescribed burning, and other fossil fuel combustion processes (Science Applications International Corporation, 2001). As NO_x molecules collect in the atmosphere, they are deposited back into the soil via precipitation, fog/cloud intercepts and dry deposition (particles/gases). Excess nitrogen and NO_x in the air contribute to a soil condition called nitrogen saturation. Nitrogen is the mineral nutrient that plants require in the greatest quantity. However, forest trees have adapted to growing on nitrogen poor soils. When nitrogen is in abundance, trees may consume excessive quantities—this could be detrimental to their long-term health. When the nitrogen content of the soil is too high to be absorbed naturally by native vegetation, the excess nitrogen will typically be lost by leaching from the soil and then carried off in stream water (Takemoto et al., 2000), (Fenn et al, 1996).

Camp Paivika in the San Bernardino mountains shows the effects of nitrogen-saturated soil. High levels of NO_X in stream water have been measured at Camp Paivika. As stream water from the San Bernardino mountains recharges underground aquifers and wells used by the cities of San Bernardino and Riverside, NO_X pollution of drinking water and associated effects on human health are of concern. Forests to the east may show signs of nitrogen saturation in future decades.

Effects of increased nitrogen on desert ecosystem health (Excerpted from Environmental Protection Indicators for California, Chapter 3—Ecosystem Health) (California Environmental Protection Agency, 2002): The degradation of habitat quality has led to the loss of native plants and plant communities. Habitat degradation has also increased the opportunities for non-native and invasive species. NO_X blown in from the Los Angeles and Riverside air basins have increased the nitrogen content of the soil. Off-highway and military vehicles and automobiles also contributed to the high soil nitrogen content. Since nitrogen is an important limiting factor for plants in the desert, higher levels of soil nitrogen allow a variety of exotic annuals and grasses to establish in the deserts. This creates competition with native annuals. The increased biomass then leads to an increased frequency of fires and changes in the biological communities of the desert. It has been suggested that changes in the plant communities might be related to the decline in the population of desert tortoise, which is a threatened and endangered species.


Desert Tortoise from CSUF Desert Study Center

Exotic plant species are spreading throughout the desert due to a variety of anthropogenic stressors. The extent of exotic plant species could indicate the health of desert ecosystems. The effects of exotic plant species on productivity and diversity of desert habitat is under examination. Although the number of exotic plant species in the desert is relatively small compared to other regions of California, those that have become established present a threat to the structure and function of native desert plant communities.

Research has shown that as the amount and extent of exotic plants increases, the diversity of native plant species declines. This is damaging to wildlife that relies on the native species. In addition, increasing amounts of exotic annual plants create a wildfire hazard that did not exist before these plants were established in the desert. This is a significant problem since regeneration time in the desert is exceptionally slow.

Red brome, schismus, and filaree, all non-natives, now account for the majority of the annual plant biomass in many areas of the California Mojave Desert. Fires are more frequent where the biomass of red brome is high. Also, fires have become more frequent since the invasion of red brome into the Mojave Desert region.

Effects of burning on air quality

Smoke generated by fire is considered a form of particulate matter. Increasing concentrations can cause adverse health effects and decreased visibility. Sources of smoke include wildfires, prescribed fires (fires set by humans), prescribed natural fires (fires caused by lightning source and allowed to burn), biomass waste burning, and urban enclave burning such as wood stoves and fireplaces. The effects of smoke are highly evident in the Sierra Nevada mountains where large wildfires occur frequently, prescribed burning is increasing, transport of smoke from Central Valley biomass burning in late summer, and urban wood stoves as a source of heating in late fall and winter routinely affect mountain air quality (Cahill et al, 1996).

Until recently, data on smoke related air pollution has been very limited. Most monitoring stations already in place only measure particulate matter ten microns in diameter or smaller. Smoke particles are much smaller in diameter. These particles are only picked up on PM10 gauges when extreme levels of smoke reduce visibility to two miles or less. Therefore, small to moderate smoke levels go undetected.


Smoke from grassland wildfire

In 1998, the ARB began a new monitoring program to gauge the effects of smoke on air pollution at PM2.5 monitoring levels. However, data from this new program is limited and a full assessment of PM2.5 is not readily available. The historic collection in the 1990s of PM2.5 data comes from a handful of stations of the IMPROVE (Interagency Monitoring of Protected Visual Environments) sites. These stations collect meteorological, chemical, and optical analysis and are located in uninhabited locations (Sequoia National Park, Turtle Back Dome in Yosemite National Park, and West Shore Lake Tahoe) and urban locations (Lake Tahoe Highway 50 Corridor and Yosemite Village) (Cahill et al., 1996).

An analysis of smoke related air pollution from the Sierra Nevada Ecosystem Project in 1996: Aerosol data from remote sites in the Sierra Nevada mountains indicates that the most severe impacts on air quality come from large wildfires but show little effects from prescribed fires. Data collected in 1994 from an IMPROVE air sampler at Turtleback Dome in Yosemite National Park showed that the highest levels of particulate matter occurred during a prescribed natural fire, a type of burn caused by natural events and allowed to burn. However, throughout the over 30 days of this prescribed natural fire, PM10 levels exceeded State air quality standards only once. Prescribed fires at remote locations had little to no affect on air quality.

Large wildfires produce severe short-term impacts on air quality but since they are rare and brief, the potential impacts to human health are minimal.

In contrast, Yosemite Village, a heavily developed area within Yosemite Valley, experienced routine high PM10 levels during the same period. The presence of campfires, fireplaces, and vehicles as well as a nighttime inversion layer resulted in high levels of pollution in the valley, despite lower levels outside the valley experiencing fire.

The Lake Tahoe Basin followed a similar pattern. In winter, high particulate levels registered in the Highway 50 corridor of the Lake Tahoe Basin. On the contrary, the West Shore monitoring station had low levels of particulate pollution. An analysis of the pollution showed high levels of both organic matter and non-soil potassium. This indicates the primary polluter was wood smoke from residential wood burning. Only one time period recorded elevated levels of smoke at both Lake Tahoe sites. This can be attributed to cropland burning in the Sacramento Valley and prescribed burning in the surrounding national forests in late fall. These elevated smoke levels were much shorter in duration and roughly 20 percent less than winter pollution peaks from residential wood fires (Cahill et al., 1996).

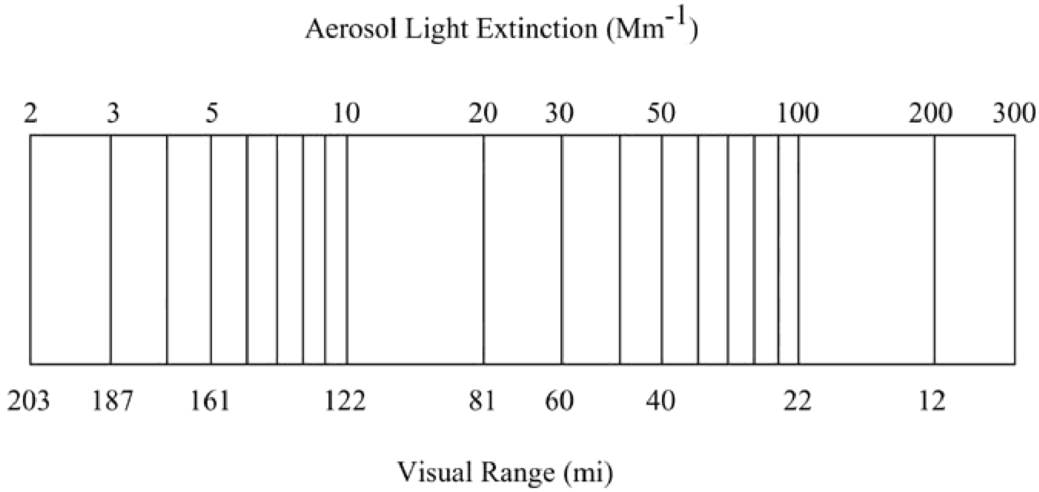
This data suggest prescribed burns are not as important as residential wood combustion and campfires as a source of particulate matter pollution in populated areas of the Sierra Nevada mountains. Large wildfires produce severe short-term impacts on air quality. However, these events are rare and typically short-lived so the potential impacts to human health are often low. Additionally, prescribed burns occur more frequently but the fuel consumed is moderate. Burns are also prescribed during times of advantageous meteorological conditions to help dissipate particulate matter pollution (Cahill et al., 1996).

Visibility

The term visibility refers to the clarity with which scenic vistas and landscape features are perceived at great distances. Visibility obscuring mountains and other scenery lowers airport safety, real estate values, and discourages tourism. Visibility is affected by pollutant concentrations, the viewing angle, relative humidity, cloud characteristics, and other physical factors such as color contrast between objects. Without the effects of human-caused air pollution, a natural visual range is estimated to be about 140 miles in the western United States.

Two metrics are used in this assessment to describe visibility: visual range and light extinction coefficient. “Visual range” is the most commonly used visibility metric and is defined as the greatest distance at which a large dark object can be seen against the background sky. The “aerosol light extinction coefficient” is a visibility metric used to describe reduced visibility and represents the attenuation of light per unit distance due to the scattering and absorption by gases and aerosols between the source and receptor. The light extinction coefficient is measured directly by a coefficient of extinction in 10 inverse megameters (mm^{-1}). See Figure 5 for the relationship between these visibility metrics.

Figure 5. Relationship between the light extinction and visual range scales



Source: EPA, 2002

National standards

Nation visibility standards call for improvement in visibility on the most impaired days and no change in visibility in the least impaired days.

The National standard for visibility, called the Regional Haze Rule, was created in 1990 by the U.S. EPA to protect visibility in national parks and wilderness areas (Federal Class I areas). The final rule calls for states to establish goals aimed at improving visibility in the mandatory Federal Class I areas and to develop long-term plans for reducing pollutant emissions that contribute to visibility degradation. The rule gives the states the flexibility to develop cost-effective strategies for pollution reductions and encourages states to coordinate with each other through regional planning efforts. The Regional Haze Rule calls for visibility improvements on the most-impaired days (the 20th percentile of the days with the worst visibility) and no additional visibility impairment on the least-impaired days (the 20th percentile of the days with the lowest calculated impairment).

Types and sources of pollutants that affect visibility

IMPROVE air quality monitoring sites collect the most comprehensive data relative to visibility problems. An IMPROVE air sampler is a filter mechanism with a series of four samplers that concurrently collect two 24-hour particulate samples weekly (Science Applications International Corporation, 2001).

Aerosol suspended particles may originate as emissions from natural sources (e.g., sea salt entrainment and wind-blown dust) or from manmade sources (e.g., automobile exhaust and mining activities). Aerosol particles may also form in the atmosphere as gases condense or react with one another. Fine aerosol particles less than 2.5 microns in diameter are of particular concern because of their more efficient ability to scatter light particles. Although particulate matter less than 2.5 microns is often composed of numerous chemical species, chemical analyses have been used to identify and group five key contributors to visibility impairment: sulfates, nitrates, organic carbon, elemental carbon, and crustal material (Table 3).

Table 3. Atmospheric fine particles (PM 2.5) and major emission sources

Atmospheric pollutant	Primary sources		Secondary sources	
	Natural	Manmade	Natural	Manmade
Sulfate	Sea spray	Fossil fuel combustion	Oxidation of sulfur gases emitted by volcanoes, oceans, wetlands and forest fires	Oxidation of sulfur dioxide emitted from fossil fuel combustion
Nitrate	N/A	Motor vehicle exhaust	Oxidation of NO_X produced by soils, forest fires, and lightning	Oxidation of NO_X emitted from fossil fuel combustion, motor vehicle exhaust, and prescribed burning
Organic carbon	Wildfires	Open burning, wood burning, prescribed burning, motor vehicle exhaust, incineration, and tire wear	Oxidation of hydrocarbons emitted by vegetation and wildfires	Oxidation of hydrocarbons emitted by motor vehicle, open burning, wood burning, fuel storage and transport, and solvent usage
Elemental carbon	Wildfires	Motor vehicle exhaust, wood burning, prescribed burning, and cooking	N/A	N/A
Crustal material	Wind erosion	Dust from paved and unpaved roads, agricultural operations, and forestry	N/A	N/A

Source: Science Applications International Corporation, 2001

Status of visibility in monitored sites in California

Table 4 shows a comparison of selected parameters of visibility as measured by the average annual total aerosol extinction coefficients from 1994 to 1998 between the various California IMPROVE air quality monitoring sites. Sites with a greater extinction coefficients mean that there are greater impairments to visibility. As shown, Lassen National Park had the best visibility as described by having the lower average extinction coefficient and Sequoia-Kings Canyon National Park had the worst. This data suggests great variation in annual data and that different geographic regions of the state have different visibility ranges. Overall, the visual range from these sites extends from 40 miles to 100 miles. The table also suggests the sulfate and nitrate particulates are the leading pollutant affecting visibility.

Table 4: California average annual total aerosol light extinction coefficients from monitoring, 1994–1998

IMPROVE site	Calculated total aerosol extinction coefficient (mm^{-1})	Pollutant extinction coefficient (mm^{-1})				
		Sulfate	Nitrate	Organic carbon	Elemental carbon	Crustal material
Lassen Volcanic National Park	14.6	4.5	1.3	5.2	1.7	1.9
Pinnacles National Monument	30.6	9.3	6.3	6.9	3.5	4.6
Point Reyes National Seashore	42.1	20.5	10.6	4.5	1.4	5.1
Redwood National Park	40.7	24.7	7.5	4.1	1	3.4
San Gorgonio Wilderness	42.9	9.7	16.9	7.8	3.7	4.8
Sequoia-King Canyon National Park	50.5	11.4	11.2	14.5	5.3	8.1
Yosemite National Park	23.2	6	2.8	8.8	2.4	3.2
Average	34.9 + - 12.7	12.3 + - 7.5	8.1 + - 5.3	7.4 + - 3.6	2.7 + - 1.5	4.4 + - 2.0

mm^{-1} - inverse megameters

Source: EPA, 2002

Trends in California visibility

Table 5 shows the visibility trend information for IMROVE sites monitored between 1994 and 1998. Trend information was collected by categories of level of impairment. The least-impaired days category represents the average visibility score for the 20 percent of the days with the lowest particulate matter concentrations and thus, the best visibility. The trend results suggest that no monitored site had degrading visibility trends in any impairment category. One site, specifically Pinnacles National Monument, had improved visibility in all categories of impairment. See EPA Visibility Report.

Visibility trends in all monitored national parks; monument or wilderness areas show no changes in visibility quality and in some locations improving conditions.

Table 5. Visibility trends at IMPROVE monitoring locations, 1994 – 1998

Trend	Least-impaired days	Mid-range days	Most-impaired days
Improved visibility	Pinnacles National Monument	Pinnacles National Monument	Pinnacles National Monument Redwood National Park San Gorgonio Wilderness
No statistically significant change in visibility	Redwood National Park San Gorgonio Wilderness Yosemite National Park Point Reyes National Seashore Lassen Volcanic National Park	Redwood National Park Lassen Volcanic National Park San Gorgonio Wilderness Yosemite National Park	Lassen Volcanic National Park Point Reyes National Seashore Yosemite National Park

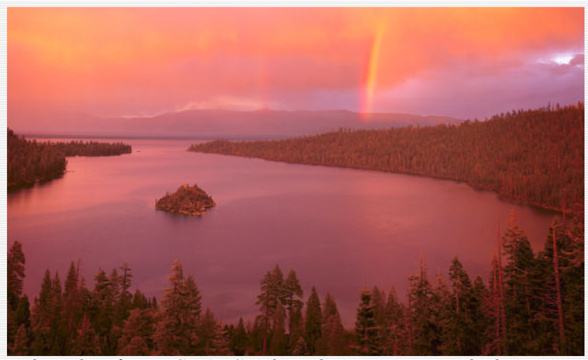
Source: EPA, 2002

Acidification

Deposits of acids caused by humans from the air to water sources are being studied at fragile, high-elevation lakes in the Sierra Nevada mountains. Currently, chronic acidification caused by humans is not deemed a particular problem. The soil and rock of the Sierras is extremely capable of neutralizing acids added to the watershed. The 1980 National Surface Water survey found no lakes with an Acid Neutralizing Capacity of less than zero. A capacity of less than zero would indicate acid lake conditions. However, some individual episodes of acidity have been detected from summer rainfall and spring snowmelt where snowmelt pH levels are reduced to 5.5 to 5.8 for a period of up to one week (Melack, 1995; Brown, 1995; Stoddard, 1995).

Other studies focus on the effects of acid on amphibians and other aquatic species at high-elevation lakes. These locations are deemed most susceptible to acidification. They can indicate future wet and dry acid deposition. While low acid conditions are widespread, future concern over development of energy power sources using fossil or wood fueling products presents a threat to acidification of Sierra Nevada lakes (Brown, 1995).

Lake Tahoe case study (excerpted and adapted from Air Quality in Lake Tahoe Basin Watershed Assessment): The uniqueness of the Lake Tahoe Basin air shed makes air quality models developed for general air sheds ineffective. The nexus of lake clarity, forest health, visibility, and human health make modeling this ecosystem particularly challenging. Due to limited knowledge of variable parameters, such as source strength, meteorology, deposition, and often composition, model development is made more formidable.



Lake Tahoe from USDA FS Lake Tahoe Basin Watershed Assessment

Lake Tahoe presents a particularly sensitive air quality situation. While the air quality remains quite good relative to other urban areas with few violations of air quality standards, the basin has unique air quality characteristics. These unique characteristics include unique scenery, a nutrient sensitive lake, and high elevation that compound health risks. Also, the basin has both localized pollution sources from increased recreational and permanent population expansion combined with interbasin transport of pollutants to a landscape that retains pollutants.

The Lake Tahoe air quality situation has several particular complexities:

- Great mountainous divides surround Lake Tahoe. These attributes create local climate conditions that trap air in the basin by regularly creating inversion layers. Additionally, rapid radiation cooling at night creates down slope winds. Both of these conditions contribute to retaining and circulating pollutants transported to and created within the basin.

- The inversion-based basin collects and traps pollutants from local sources, such as vehicular, urban, and forest-burning emissions. These inversions limit the air into which pollutants can be mixed, thereby creating significant pollution levels. Transport of pollutants from the Sacramento Valley Air Basin increases concentrations of both O^3 and fine particulates like sulfates, nitrates, and smoke. These fine particulates come from industrial, urban, vehicular, agricultural, and forest sources in western slopes of the Sierra Nevada Mountains, the Sacramento Valley, and the San Francisco Bay Area.

- Increasing human activities in the basin generate pollution sources from vehicle emissions and winter firewood burning. As these sources continue increasing, small particulate nitrates are a real concern for visibility, nitrate deposition in lakes, and human health.

- Smoke from wildfires on the western slope of the Sierra Nevada can blanket the basin. This reduces visibility, violates health-based air standards, and causes algal blooms in the lake.

- Lake Tahoe is relatively high in elevation and is a small watershed. It requires hundreds of years to replenish its water supply. Deposition of pollution into the lake can take many decades to process.

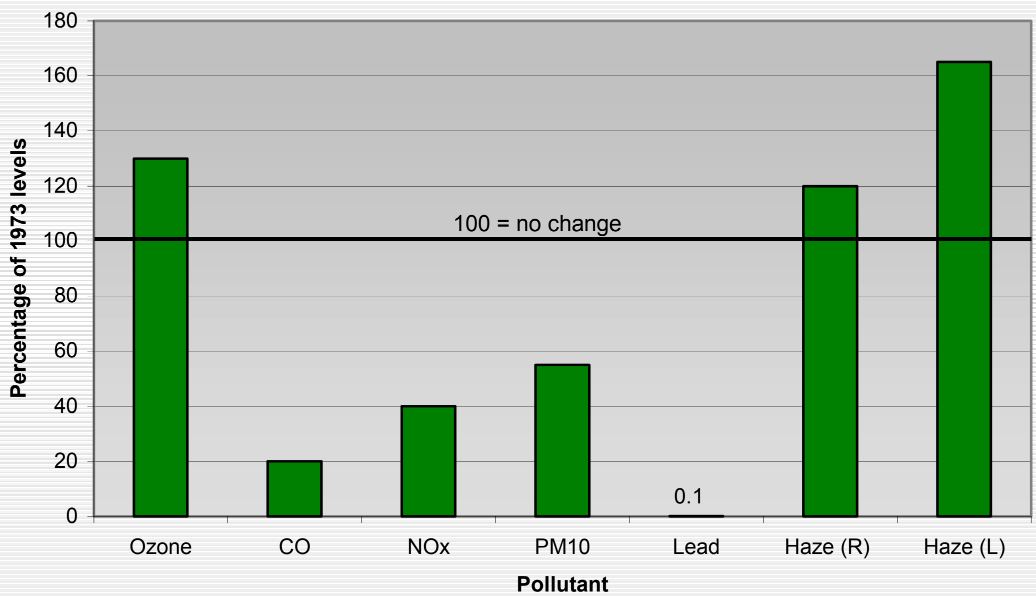
Current status of and trends in air quality at Lake Tahoe: All gaseous and particulate matter pollutants are presently well below California, federal, and basin air quality standards. All pollutants except O_3 continue to decrease based on improved fuels and vehicular engines (ARB, 1999). The steady increase in O_3 at Lake Tahoe from 1977 to the present is unique in all of California.

For all other urban sites with 20 years of data, O_3 has declined. The result is that O_3 is rising to levels close to the California and the proposed new federal standard (presently on hold due to court rulings). It is also close to levels at which chronic O_3 damage to vegetation could become more serious than the present light to moderate injury levels (Cahill et al., 1996).

Particulate matter affects visibility and human health. Fifty percent originates from valley sources and the remaining 50 percent originates from local sources during summer pollution monitoring. Winter particulate was found to be primarily from local sources.

Figure 6 shows an overall summary of pollution conditions over time. This figure shows relative pollution levels monitored at South Lake Tahoe. Note the sharp reduction in CO, NO_X, PM10, and lead over this period. Ozone increases at South Lake Tahoe are unique to urbanized areas over this period, possibly resulting from increased development of the foothill communities east of Sacramento.

Figure 6. Air quality at urbanized sites in South Lake Tahoe (1993 versus 1973)



Haze (L) – Local haze, South Lake Tahoe; Haze (R) – Regional haze, basin wide

Source: Lake Tahoe Watershed Assessment, 2000

Effects of air pollution in Lake Tahoe: While pollution monitoring suggests an acceptable pollution condition, the effects on visibility, lake clarity, forest vegetation damage, and human health are of concern.

- **Visibility:** Visibility conditions have been steadily decreasing. Transported urban pollutants primarily affect visibility. Local automobiles contribute little to visual range decreases. During winter, local visibility conditions are primarily affected by woodburing stove and fireplace smoke.
- **Water clarity:** Airborne algae nutrients are of concern to water clarity. However, the role of these nutrients is not certain. Particulate sources of nitrogen have declined over the 20-year period of continuing lake clarity reduction. Phosphorus, mainly in disturbed soil, is now considered the important limiting factor for algae growth and reduction in lake clarity. Phosphorus has also been deposited from airborne wood burning smoke and agricultural burning.
- **Vegetation:** The major documented impact of air pollution in the Sierra Nevada forest is O_3 on Jeffery pines (Cahill et al., 1996). Ozone damage ages the trees. This reduces productivity through premature aging of the pine needles, reducing sap flow, and making the tree vulnerable to drought, insect attack, and other stress factors. Data has been developed which indicates a threshold O_3 concentration below which damage to the Jeffery pine was minimal (concentration multiplied by hours above 0.09 PPM). Although, this level is rarely reached at Lake Tahoe presently, it may be routinely violated in ten years if these trends continue. Surveys of O_3 injury to forests in the Lake Tahoe basin showed only light to moderate impacts, but the characteristic O_3 mottle was and is clearly evident, especially on high foliage in the tallest trees (Pedersen and Cahill, 1989).
- **Human health:** The primary impact of Lake Tahoe air pollutants on human health used to be the relatively high CO levels of the 1970s. CO concentrations have since been greatly reduced. At present, the high PM2.5 levels in the winter in urbanized areas are the major concern. However, a recent study for the American Lung Association (Cahill et al, 1998) showed low impacts on cardio-pulmonary and stroke markers at Lake Tahoe.

See Air Quality in Lake Tahoe Basin.

Findings on future of air quality in California

Future prediction of air quality continues to depend on metropolitan pollution control, particularly as it relates to O_3 production. This is especially true within the South Coast, Sacramento Valley, and San Joaquin Valley air basins. Stricter air standards coupled with technological advances are currently improving air quality. This will help to reduce future O_3 precursors. However, residential expansion compounded with current agricultural practices will continue to put a strain on air resources particularly within the San Joaquin Valley.

Air quality in the Sierra Nevada mountains will be impacted by increased emigration into the area. Localized pockets of urbanization will increase traffic and create changes in land use. The Sierra Nevada mountains are also subject to pollutant transport originating from the San Joaquin and Sacramento Valleys. Local inversion layers combined with residential wood combustion will continue to create localized PM10 and PM2.5 problems. To a lesser extent, prescribed burns and wildfires will also affect PM10 and PM2.5 levels in the Sierra Nevada mountains.

The southern Sierra Nevada mountains are of particular concern. Here, the rapid expansion of both residential and industrial/agricultural growth in the southern San Joaquin Valley has the O_3 production capability to seriously injure native Jeffery pine and Ponderosa pine trees. Desert rangeland areas within

Southern California will undoubtedly experience the impacts from increased urbanization and transport of pollutants from the Los Angeles and San Diego regions.

Glossary

aerosol light extinction coefficient: A visibility metric used to describe reduced visibility and represents the attenuation of light per unit distance due to the scattering and absorption by gases and aerosols between the source and receptor.

ambient: Encompassing on all sides; circumfused; investing.

anthropogenic: Caused by humans.

ARB: California Air Resources Board.

attainment status: A pollutant is designated attainment if the state standard for that pollutant was not violated at any site in the area during a three-year period.

CO: Carbon monoxide.

EPA: U.S. Environmental Protection Agency.

FPM: Forest Pest Management.

IMPROVE: Interagency Monitoring of Protected Visual Environments.

inversion layer: An atmospheric condition in which the air temperature rises with increasing altitude, holding surface air down and preventing dispersion of pollutants.

micron: A measure of length; the thousandth part of one millimeter; the millionth part of a meter.

mm^{-1}: Inverse megameters.

NO_2: Nitrogen dioxide.

NO_X: A general group of nitrogen compounds often termed oxides of nitrogen or nitrogen oxides.

non-attainment status: A pollutant is designated non-attainment if there was at least one violation of a State standard for that pollutant in the area.

non-attainment/transitional status: A subcategory of the non-attainment designation. An area is designated non–attainment/transitional to signify that the area is close to attaining the standard for that pollutant.

O_3: See **ozone**.

OII: Ozone Injury Index.

ozone: An unstable, poisonous allotrope of oxygen that is formed naturally from atmospheric oxygen by electric discharge or exposure to ultraviolet radiation. It is also produced in the lower atmosphere by the photochemical reaction of certain pollutants.

particulate matter: Airborne particles 10 microns in diameter and smaller.

PM10: Particulate matter 10 microns or smaller in diameter.

PM2.5: Particulate matter 2.5 microns or smaller in diameter.

PPM: Parts per million.

SNEP: Sierra Nevada Ecosystem Project.

SO_2: Sulphur dioxide.

µg/m^3: Micrograms of particulate matter per cubic meter of air.

unclassified status: A pollutant is designated unclassified if the data are incomplete and do not support a designation of attainment or non-attainment.

Visual range: The greatest distance at which a large dark object can be seen against the background sky.

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